1

Basic Characteristics of Ammunition: From Handguns to MANPADS

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Introduction

In policy-relevant small arms research ammunition receives far less attention than weapons. Most researchers and policy makers are more familiar with pistols, rifles, or machine guns than with the different types and calibres of projectiles fired by each weapon. One reason for this is the sheer diversity of ammunition, ranging from the basic pistol cartridge to sophisticated explosive projectiles for man-portable air defence systems (MANPADS). In order to understand the issues surrounding the use and misuse of small arms and light weapons it is necessary to understand the roles and characteristics of ammunition as well as the factors affecting its production and distribution. Without this knowledge it is difficult to develop effective policies—both domestic and international—to address the problems associated with the unchecked proliferation and use of small arms.

Many authors have provided comprehensive studies of the technical characteristics of ammunition (e.g. Courtney-Green, 1991; Allsop et al., 1997; Ness and Williams, 2005). This chapter presents the broad categories of ammunition for small arms and light weapons and is intended as an introduction to its diverse technical characteristics in order to provide a basic understanding of ammunition in the context of historical, current, and possible future developments. It is therefore a starting point for those who wish to understand how ammunition functions, and how it may potentially be targeted by national and international initiatives.

Section 2 of this chapter is an overview of the history of ammunition. Section 3 presents the different types of ammunition that are in contemporary use. Section 4 describes the various damaging effects that each type of ammunition may have on human beings and infrastructure. Section 5 is a brief overview of recent developments in ammunition technologies, and Section 6 analyses how international attitudes and responses to the proliferation of ammunition may change in the near future. Section 7 presents conclusions. The chapter's most salient conclusions can be summarized as follows:

- Ammunition that requires sophisticated technology, such as guided missiles, is only produced in a small number of countries but traditional cartridge-based ammunition producers are far more widespread.
- The accuracy and destructive capacity of ammunition, and of light weapons in particular, are continuously increasing.
- The latest developments in ammunition tend to blur current understandings of the distinction between small arms and light weapons.
- These developments seem set to bring yet more firepower and accuracy to the battlefield, thereby increasing the destructive potential of war and necessitating new approaches to controlling the proliferation and use of ammunition.

A brief history of ammunition

Small arms ammunition

Propellant and primers

Gunpowder (also known as 'black powder') is a mixture of charcoal, sulphur, and potassium nitrate. It was originally produced in ancient China and was first developed as a propellant for use in cannons in Europe around the 14th century (Krause, 1995, pp. 36–37; Folly and Mäder, 2004, p. 374).

Gunpowder was originally very easy to ignite, a problem that was mitigated by the development of corned powder in the 1420s, which made the different components of the mixture more stable (White, 1964, pp. 100–01). Black powder remained very susceptible to moisture, however, and its very low rate of combustion made storage hazardous. In addition, it produced a lot of residue on firing, which tended to foul the barrel of the weapon. The heavy smoke it produced limited shooting accuracy and revealed the shooter's position (Folly and Mäder, 2004, p. 374).

Black powder nevertheless remained in use until the late 19th century, when it was replaced by nitrocellulose-based smokeless powder (Allsop et al., 1997, p. 8). In addition to being more powerful, the smokeless powder left the barrel relatively clean and had better storage and transportation properties. The switch to smokeless powder facilitated the development of more complex weapons, notably machine guns, which required a powder that would not foul complicated firing mechanisms (Headrick, 1981, pp. 99–100).

Important improvements were made to the stability and functioning of ammunition in the early 19th century. Primers, which are used to ignite the propellant, had previously been made from fulminate of mercury—a substance that is particularly unstable when stored. Chlorate mixtures had been tried in the early 1800s but these resulted in severe corrosion and rusted the weapon's chamber. When alternative lead styphnate mixes were developed, they proved more stable and did not harm the weapon (Drury, 1999).

Projectiles

Early projectiles were made of stone, then iron, and later of the more dense metals such as lead (Krause, 1995, p. 37). Lead bullets were at first spherical and loaded through the muzzle of unrifled smoothbore weapons.[1] Rifles were developed early in the history of military small arms but took much longer to load than smoothbore weapons because the bullet had to be wrapped in a piece of leather to allow it to grip the rifling of the barrel. One consequence of this loose fit was that rifles suffered from fouling in the barrel (Headrick, 1981, p. 87).

In 1848, however, the development of the Minié bullet made possible the large-scale adoption of rifles as a military small arm. This new bullet was conical in shape with a hollow base, and it was easy to load. Moreover, it expanded on firing to fit the rifling of the barrel, thereby providing greater accuracy and reducing fouling (McNeill, 1983, p. 231).

Throughout the 19th century the calibre of guns and ammunition progressively reduced, from the 19 mm ball of the Brown Bess musket of the first quarter of the century, to the less than 8 mm rounds used in some repeater rifles in the 1890s (Headrick, 1981, p. 99). The last quarter of the 19th century also saw the development of steel- or copper-jacketed bullets with a lead core. These were harder and more resistant to the heat in the barrel (DeClerq, 1999).

Cases and cartridges

The first cartridges appeared in the first half of the 17th century but were more of a 'shooting kit' than a real cartridge. Cartridges combined both powder and bullet in a tube of thick paper. The shooter tore the paper apart, poured the powder into the muzzle of the weapon, and then inserted the bullet. The paper was used as a wad to prevent the bullet from falling out of the barrel (Allsop et al., 1997, pp. 11–12). Paper cartridges allowed quicker loading (Allsop et al., 1997, p. 11) and, by regulating the amount of powder used in every firing, more consistent and predictable shooting. They also reduced jamming and exploding barrels.

The next step was the invention of the self-contained cartridge in the mid-19th century. This consisted of a single case holding a primer, propellant, and bullet. The cartridge was designed to be inserted whole into the breech of a weapon; a characteristic which defines breech-loading weapons. Made of brass, the cartridge allowed a tighter seal within the weapon's barrel, which better contained the propellant gases and consequently improved the weapon's range (DeClerq, 1999).

Smokeless powder, lead styphnate primers, steel- or copper-jacketed bullets, and brass breech-loading cartridges are all features of contemporary ammunition and the technology has not changed much in recent decades (Small Arms Survey, 2005, p. 10). For instance, the 9 mm Parabellum round developed 100 years ago is still a favourite of contemporary armies—although it is worth noting that powders and primers have improved in quality since that time (Marchington, 1997, p. 8).

Light weapons ammunition

The evolution of explosive light weapons ammunition has followed a different path to that of small arms ammunition. Man-portable, direct-fire, rocket-propelled munitions only appeared in the mid-20th century—after the development of sufficiently small rocket motors.

The Russian RPG-2 anti-tank grenade launcher (which is technically a recoilless rifle) was adopted by the Soviet army in 1949. The PG-2 High Explosive

Anti-Tank (HEAT) grenade used in the RPG-2 contained a charge of propellant and six stabilizing fins that opened during flight (Modern Firearms and Ammunition, 1999). The weapon was replaced in 1962 by the much higher performance, and now ubiquitous, shoulder-fired anti-tank rocket launcher, the RPG-7 (Jones and Cutshaw, 2004, pp. 432–33; Modern Firearms and Ammunition, 1999).

The development of guided weapons came much later than weapons such as the RPG-7 and other anti-tank rocket launchers. MANPADS, for instance, were first mass-produced at the end of the 1960s. The earliest models included the US FIM-43 Redeye (1967), the British Blowpipe (1968), and the Russian SA-7 (1968) (Small Arms Survey, 2004, p. 82).

There were also major technical developments in indirect-fire munitions, such as those for mortar rounds, in the 20th century. A significant impetus for these developments was trench fighting in the First World War, which required a weapon that could be fired from one trench to another in a high arc trajectory. The Stokes trench mortar, for instance, combined powerful shells and a long range. The evolution of mortar rounds was marked by a reduction in calibre, which made the weapons more mobile. Mortars developed from heavy weapons used primarily for siege warfare into man-portable weapons (Canfield, 2000).

The First World War also encouraged new developments in grenade technology. Grenades had been used for centuries but were more or less abandoned in the 18th century. Most of the earlier designs consisted of a simple metal container filled with gunpowder. They had increasingly been regarded as dangerous in this form, and as of little use on the battlefield. However, the requirements of trench warfare, combined with newly developed mechanical ignition systems, reintroduced grenades as a practical infantry weapon in close-quarter fighting.

Basic categories of ammunition for small arms and light weapons

The 'Small arms and light weapons' listed in the *Report of the Panel of Governmental Experts on Small Arms* by the Expert Group of 1997[2] encompasses a variety of weapon types that, in turn, employ very different types of ammunition. One possible way of analysing small arms and light weapons ammunition is to divide it into two categories, based on the distinction between traditional cartridge-based and non-cartridge-based ammunition. These categories can be further subdivided by calibre and according to whether projectiles are guided or unguided (Figure 1).

The distinction between cartridges and explosive projectiles is important for a number of reasons. There are distinctions between the level of technology required to produce 'traditional' cartridge-based ammunition, and more sophisticated ammunition (Small Arms Survey, 2005, pp. 45–46). It is also a distinction that broadly follows the division between small arms and light weapons (Table 1). While all small arms use cartridge-based ammunition, the majority of currently available light weapons fire explosive ammunition.

Table 1
Small arms and light weapons in *United Nations Report of the Panel of Governmental Experts on Small Arms*

Type of weapon*	Cartridge-based	Guided projectile	Explosive projectile
Small arms:			
Revolvers and self-loading pistols	Yes	No	No
Rifles and carbines	Yes	No	No
Assault rifles	Yes	No	No
Sub-machine guns	Yes	No	No
Light machine guns	Yes	No	No
Light weapons:			
Heavy machine guns	Yes	No	No**
Hand-held under-barrel and mounted grenade launchers	Yes	No	Yes
Portable anti-tank and anti-aircraft guns	No	No	Yes
Recoilless rifles	No	No	Yes
Portable launchers of anti-tank and anti-aircraft missile systems	No	Yes	Yes
Mortars of less than 100 mm calibre	No	No	Yes

* **Source:** *United Nations Report of the Panel of Governmental Experts on Small Arms* (UN, 1997, section III, para. 26)

** Explosive ammunition for some large-calibre machine guns is available but remains very rare.

Cartridge-based ammunition can be divided into categories by calibre. The distinction between calibres below 12.7 mm and those of 12.7 mm and above broadly respects the small arms–light weapons distinction.[3] This distinction matters for several reasons. In practical terms, it reflects the higher proportion of small arms to light weapons in service across the world. Small-calibre assault rifles constitute the personal weapon of individual combatants, while light weapons may be distributed only one or two per squad or section. This fact, in turn, affects the type and number of rounds of ammunition manufactured because of the disparity in the number of weapons in service in any armed force. Also, the 12.7 mm distinction serves as a rough guide to whether the weapon is used predominantly by civilians or military personnel. With a few exceptions, such as .50 calibre pistols and rifles, most weapons of 12.7 mm or greater calibre are designed explicitly for military use—and used as such.

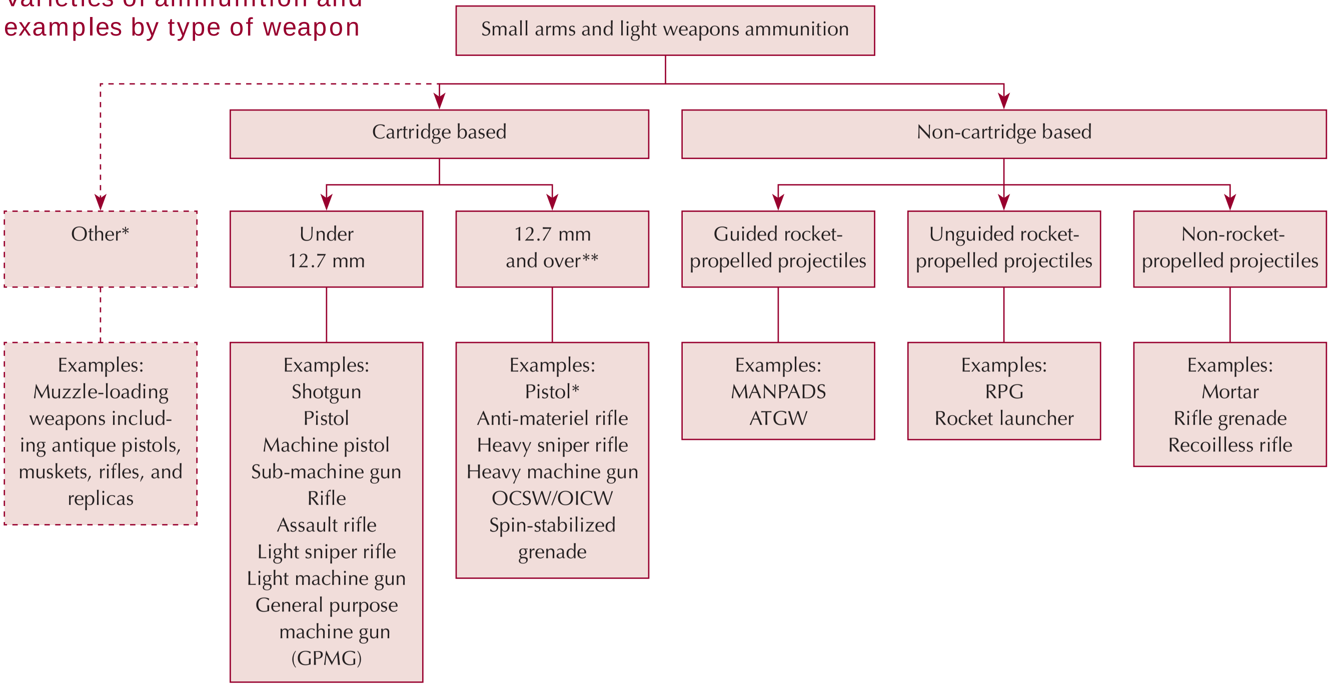
Grenades, explosives, and landmines are also included in the UN definition of ammunition. Anti-personnel and anti-tank grenades are functionally similar to small arms and light weapons ammunition, such as cartridge-based ammunition and missiles, because they are also designed to project force (see Box 1). Explosives (including improvised explosive devices) and landmines have different characteristics that distinguish them from small arms and light weapons ammunition (see Box 1).

Box 1 Explosives and landmines

The UN defines explosives and landmines as weapons 'manufactured to military specifications' (UN, 1997, section III, para. 24). Improvised explosive devices, therefore, are outside this definition. The inclusion of explosives, which are contained in such devices but also in all types of small arms and light weapons ammunition, is problematic on a number of counts: their applications are many and military explosives do not differ greatly from explosives used for civilian applications—such as for demolition or blasting. Furthermore, explosives can exist simply as pure condensed explosives—such as Semtex-H or C4—or they can be integral parts of a larger weapons system—such as the charge in a grenade or artillery shell. Explosives designed for use in combat usually belong to the second category. Most are fused to explode either on impact or after a period of time determined by the operator.

Landmines are self-contained explosive devices just like grenades. There is, however, one qualitative difference between grenades and landmines with regard to their use. Grenades are designed to enable an individual to project firepower onto a designated target, while landmines are essentially passive and do not discriminate between targets. They form a study area in their own right.

Figure 1
Varieties of ammunition and examples by type of weapon



* Very limited production and use

** Generally less than 40 mm

Note: Hand grenades fall under the United Nations definition but differ markedly from the ammunition shown above in that they are self-contained, comprising both ammunition and weapon. They are not included in the current classification.

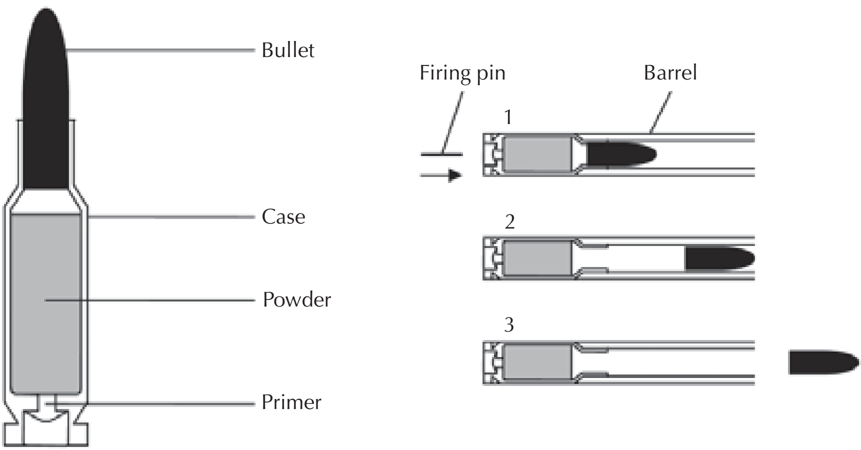
Cartridge-based ammunition

The cartridge is a self-contained unit comprising the cartridge case, the primer, the propellant (powder), and the projectile or 'bullet' (Figure 2). All weapons that fire cartridge-based ammunition have a barrel, which is integral to the process of delivering energy, momentum, and direction to the bullet.

The operating principles of all weapons firing cartridge-based ammunition are the same (Figure 2). The cartridge partially seals the firing chamber of the weapon. On firing, a pin strikes the primer at the base of the cartridge (1) and ignites it. This ignites the powder, which burns rapidly and generates expanding gases. The gases are forced down the length of the barrel, pushing the bullet in front of them (2) and eventually out of the barrel (3). Simultaneously, the cartridge case expands, thereby completing the firing chamber seal. The momentum imparted by the process propels the bullet but there is no process within the bullet that sustains movement. As a consequence, the bullet begins to lose velocity shortly after it leaves the barrel.

Cartridge size differs from weapon to weapon not only in the calibre (i.e. diameter) of the bullet, but also in the overall length of the case (e.g. 5.56 x 45 mm denotes a round of calibre 5.56 mm with a case length of 45 mm). Longer cases contain more powder, which can give more energy and thus higher velocities

Figure 2
Anatomy and operation of cartridge-based ammunition

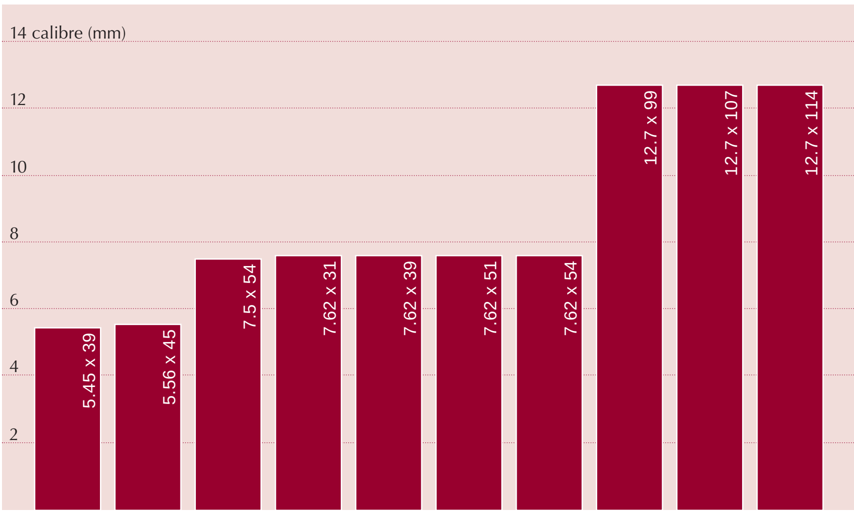


to the bullet. A given calibre can be employed in different types of weapons. Calibre .50 bullets, for instance, can be used in the Browning M2 heavy machine gun or in a pistol, but the .50 bullets used in heavy machine guns are around twice the length and weight of the pistol bullets, and they have around twice the muzzle velocity. In the United States cartridges are usually designated by a name or acronym. For instance, a .45 'Auto Colt Pistol' (ACP) round is 0.45 inches (11.43 mm) in calibre and has a case length specific to ACP ammunition of 22.79 mm (Ness and Williams, 2005, pp. 36–37).

Small calibre cartridge-based ammunition

Small calibre cartridge-based ammunition ranges from the smallest cartridges to those of just under 12.7 mm calibre. This cut-off point is a simple interpretation of the United Nations definition quoted above that places heavy machine guns (which fire ammunition of 12.7 mm calibre or above) in the category of light weapons. There is, moreover, a clear discontinuity in military calibres between 12.7 mm and the next smallest cartridge. Figure 3 shows the ammunition used in the 66 most commonly stocked assault rifles, light machine guns, and heavy

Figure 3
The most common calibres of cartridge-based ammunition



Collated data from Jones and Cutshaw (2004).

Table 2
Ammunition standards

Types of weapons	NATO standards	Warsaw Pact standards
Assault rifles, light support weapons	5.56 x 45 mm	7.62 x 39 mm
Assault rifles, self-loading rifles, sniper rifles, light machine guns	7.62 x 51 mm	7.62x 54 mm
Pistols	9 x19 mm Parabellum	7.62 x 25 mm, 9 x 17 mm
Heavy machine guns, sniper rifles, anti-materiel rifles	12.7 x 99 mm	12.7 x 107 mm, 12.7 x 114 mm

Collated data from Jones and Cutshaw (2004).

machine guns in the world. It demonstrates the discontinuity between assault rifle and light machine gun calibres up to 7.62 mm, and heavy machine gun calibres of 12.7 mm and over. There are very few military long-arms that fire calibres between 7.62 mm and 12.7 mm.

The data in Figure 3 also suggests that, in military ammunition at least, there is a very small range of calibres in frequent use throughout the world. This is linked to the legacy of the polarization of armament sources during the cold war between NATO and Warsaw Pact standards (Table 2). This is particularly true of assault rifles and machine guns—the primary infantry weapons for which standardization into as few calibres as possible is essential from a logistical perspective. However, across the globe, military pistol ammunition is far more diverse in its range of calibres than other ammunition. Many soldiers carry pistols as backup weapons and can choose from a wide range of products and calibres available on the civilian market.

Non-military ammunition is generally more varied in calibre. This is because it fulfils a wider range of functions including: small cartridges for concealed-carry pistols; specialist large-calibre pistol ammunition for hunting; match-grade rifle ammunition for target shooting; ammunition for marksmen in security forces; soft-nosed, low-velocity ammunition for law enforcement; armour-piercing and other larger calibres for big game hunting; and even rubber or plastic rounds for riot and crowd control (Box 2).

Box 2 Non-lethal ammunition

Non-lethal (or, more accurately, 'less than lethal') anti-personal weapons use a wide range of technologies that include kinetic energy, electricity, acoustics, directed energy, chemicals, or a combination of the above (Lewer and Davison, 2005, pp. 38–39). Weapons using kinetic energy replace the usual metal bullet with other impact projectiles such as rubber bullets, plastic baton rounds, or beanbags. Rubber bullets are made of plain rubber or are coated with steel; plastic baton rounds are made of tube shaped PVC (BBC, 2001); beanbags are nylon pockets containing pellets. Although these blunt projectiles are not meant to penetrate the skin, all of them have the capacity to cause serious injury and even death. Police or military forces using these rounds must maintain a long firing distance (20 metres for plastic baton rounds). They must also aim for lower limbs: a medical study on injuries attributable to plastic baton rounds in Northern Ireland showed that they had been the result of head or chest traumas (Hughes et al., 2005, p. 112). However, the low ballistic coefficient of these projectiles results in low levels of accuracy, especially at long range, and this means that they can cause unintended injuries even when properly used (Mahajna et al., 2002, p. 1799).

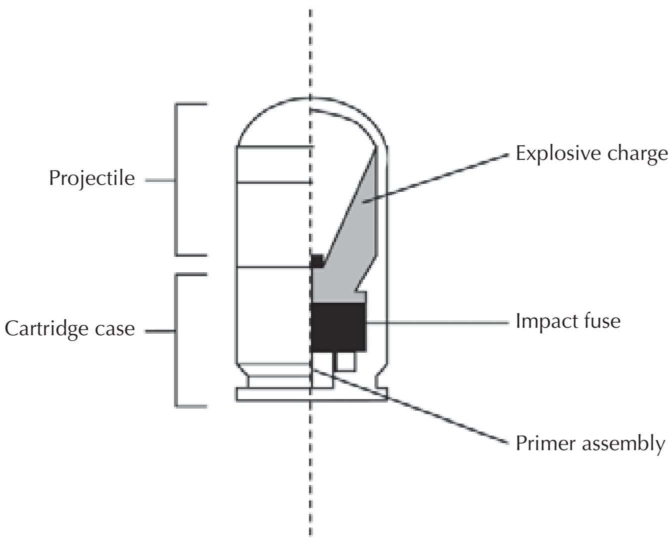
These rubber bullets and live ammunition were used by the Bolivian authorities in a confrontation with coca growers on a road between Chipiriri and Eterazama. © Lucian Read/WPN

Large calibre cartridge-based ammunition

Calibre .50 (12.7 mm) cartridges were formerly used only in medium and heavy machine guns, including those designed for anti-aircraft use. However, in the latter half of the 20th century a number of sniper rifles and anti-materiel rifles appeared on the market that use ammunition of 12.7 mm to 20 mm in calibre (the majority of these weapons use the military .50 BMG cartridge). Brands that use the .50 BMG cartridge, such as Barrett and Truvelo, have also appeared on the civilian market in the United States and South Africa, respectively.[4]

For the most part these large calibres differ very little from smaller calibre cartridge-based ammunition. However, weapons are increasingly being designed to fire explosive rounds using the cartridge system. These include spin-stabilized grenades (Figure 4) and recently developed smaller explosive munitions. Calibres for explosive munitions have tended to be far larger than other types of cartridge-based ammunition. Spin-stabilized grenades, for instance, are usually of 30 mm or 40 mm calibre, although recent developments suggest that calibres may decrease to around 25 mm (Jones and Cutshaw, 2004, pp. 394–95).

Figure 4
Anatomy of a spin-stabilized grenade



The latest versions of spin-stabilized grenades are being developed for the Objective Crew Served Weapon (OCSW) and the smaller Objective Individual Combat Weapon (OICW). The ammunition is conventional, in that it is fired from a cartridge in a barrelled weapon, but the round, which is 25 mm in diameter, is far larger than most cartridges yet smaller than previous spin-stabilized grenades. It is, moreover, fused to explode in the air over targets, an effect that is called 'airbursting' (see Figure 10). It is predicted that the OCSW will replace both heavy machine guns and automatic grenade launchers in the US armed forces (Jones and Cutshaw, 2004, pp. 394–95).

Non-cartridge-based ammunition

In contrast to cartridge-based ammunition, many varieties of non-cartridge based ammunition contain their means of propulsion within the projectile. These weapons are commonly referred to as rocket or missile systems. They also include categories of ammunition such as rocket-propelled grenades. Small arms do not operate in this way, but the majority of light weapons in the United Nations definition operate according to some variation of this principle. The basic configuration of this ammunition differs from system to system but, in all cases, the projectile consists of an explosive warhead and a rocket motor. Propulsion

Figure 5
The two main types of rocket-propelled ammunition

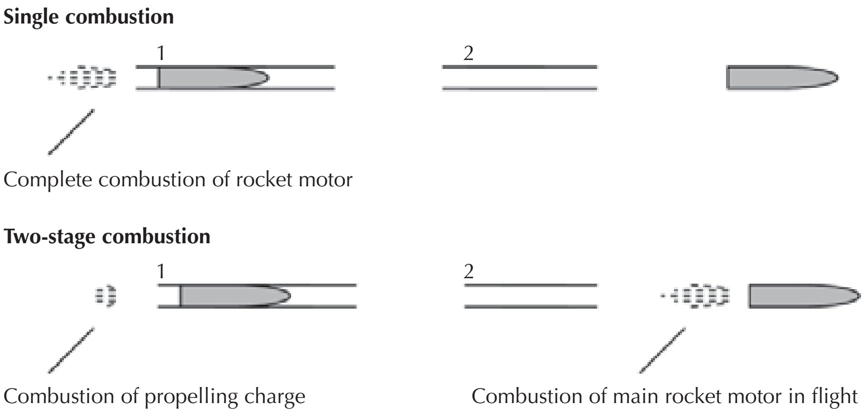
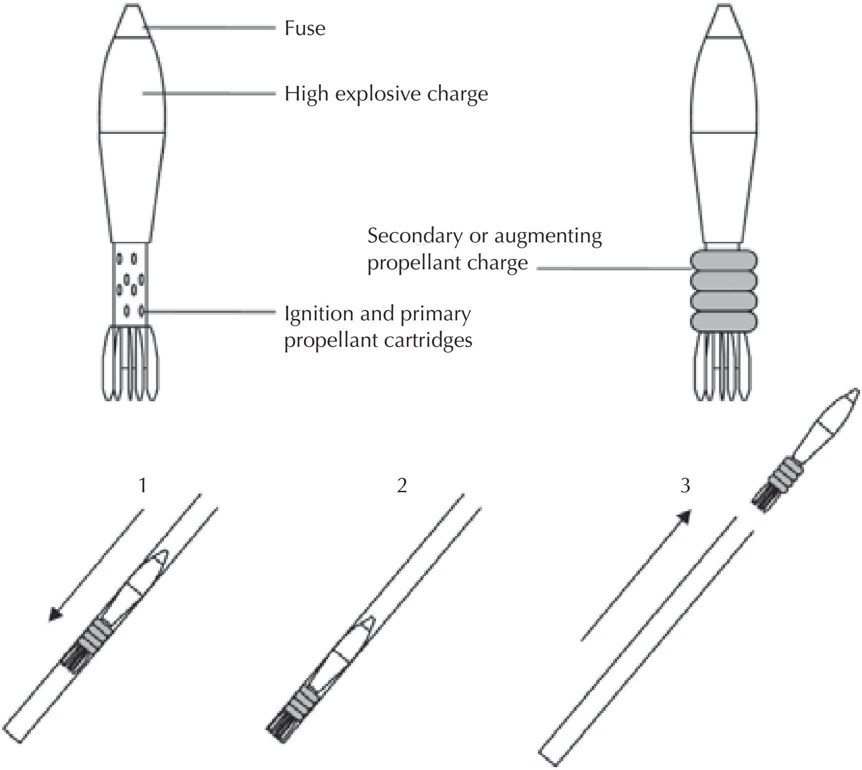


Figure 6
Anatomy and operation of a mortar



can be of two types, depending on whether the combustion of gases occurs while the projectile is in the tube or whether it is launched from the tube by a small propelling charge prior to combusion of the main rocket motor (Figure 5).

Mortars are different in that they operate in a similar way to firearms by using an integral charge (single combustion) but are not strictly cartridge based. As Figure 6 illustrates, the mortar bomb is dropped into the tube (1). It strikes a firing pin at the base of the tube (2), which ignites the ignition cartridge and the primary propellant cartridge. This, in turn, ignites the augmenting or secondary propellant charge (if used), which is arranged in bands around the base of the mortar bomb (shown in grey). The expansion of gases in the tube forces the bomb out of the tube (3).

Unguided ammunition

Unguided ammunition simply follows the trajectory assigned by the firer. Their trajectory cannot be adjusted once they have left the barrel, or launch tube, of the weapon. Unguided weapons are a common feature in most conflicts and include mortars, rocket launchers, RPGs, recoilless rifles, and rifle grenades.

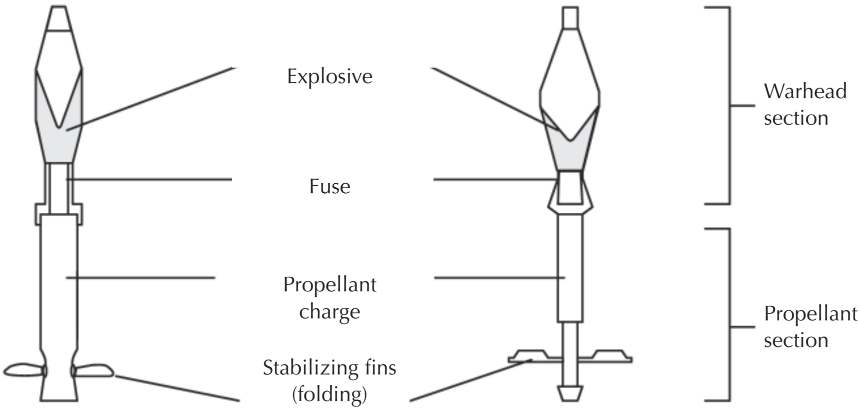
Unguided rocket-propelled light weapon ammunition can be divided into two groups—weapons that are designed to fire along the firer's line of sight, and those that are intended to fire indirectly. The former comprise weapons commonly referred to as 'rocket launchers' or 'missile systems', while the latter are mortars. Mortars fire ammunition in high arc trajectories designed to hit targets beyond the sight of the firer or behind obstacles (Figure 7).

The basic design of a direct-fire projectile includes a warhead section and a propellant section (Figure 8). This type of direct-fire weapon was developed to meet the need for a weapon to defeat armoured vehicles. The weapons and ammunition are now designed for many different roles, including targeting armoured and light vehicles, destroying hard targets such as bunkers or houses, and anti-personnel roles. Because such rocket-propelled ammunition is launched from an unrifled tube, rather than a rifled barrel, no spin is imparted to the projectile on launch. For this reason, stability is achieved through stabilizing fins, which produce a slow rate of roll in flight (Figure 8).

Indian army personnel display seized rocket-propelled grenades (RPGs) in Srinagar, 2005. © Danish Ismail/Reuters

Figure 7
The high arc trajectory of a mortar bomb

Figure 8
Two examples of unguided rocket-propelled ammunition



66 mm M72A5 HEAT ammunition for an M72 light anti-armour weapon (LAW)

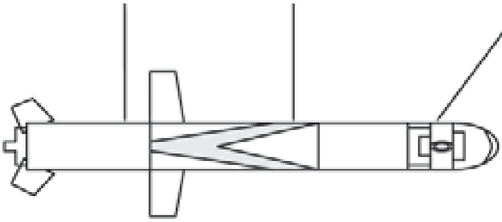
PG-7 HEAT ammunition for an RPG-7 (shoulder-fired anti-tank rocket launcher)

Guided ammunition

In contrast to unguided ammunition, guided ammunition is designed expressly to hit mobile targets, including tanks, lighter vehicles, and aircraft. Guided weapons can be directed towards the target while in flight, which allows the firer to make adjustments to compensate for the target's movement.

Types of guidance system differ greatly. In the early guided weapons, the trajectory of projectiles was adjusted in flight by wire guidance. This relied on

Figure 9
Diagram of an infrared seeking anti-tank missile



Note: A rough representation of a Javelin missile. Adapted from Raytheon and Lockheed Martin (2005).

the operator being in visual contact with the target and making adjustments while the missile flew towards it. Wire guidance is still common in some anti-tank systems, such as the Russian 9M14 Malyutka and the French Matra Eryx.

More recent types of guidance system include radar, infrared seeking, beam riding, image matching, and sensors that analyse a broad spectrum of energy sources. These do not rely on directions given by the operator after firing. They use sophisticated sensors and electronics to recognize the target, calculate its trajectory and that of the missile, and make adjustments to ensure that the two meet. The most modern systems incorporate a number of such methods, most notably, MANPADS such as the British Starstreak and the Japanese Type 91.

Figure 9 illustrates that ammunition which contains a seeker has propulsion and warhead sections that are common to unguided weapons but the warhead is set back behind the seeker, which is positioned at the front of the projectile.

Systems that employ guided rocket-propelled projectiles include anti-tank guided weapons (ATGW) and MANPADS. These are the most sophisticated light weapons in production and their manufacture is confined to a relatively small number of countries with well developed defence industries (Small Arms Survey, 2004, pp. 81–82; 2005, pp. 58–62). Because they are designed to destroy modern, rapidly moving targets, guided weapons present technological, financial, and political barriers to their acquisition, which control their proliferation to a greater extent than unguided weapons.

Hitting the target: a review of effects

The types of small arms and light weapons ammunition vary greatly and so too do their effects. Differences in effect result from variations in the range and trajectory of the weapons, and the type of impact they are designed to have on their target.

Flight ballistics

The term ballistics refers to the behaviour of a projectile in flight. Most cartridge-based small arms and light weapons are designed to fire a projectile, with a relatively flat trajectory, at a target that is within the firer's line of sight. However, there are a number of small arms and light weapons that are expressly designed to engage targets beyond the sight of the firer. These are termed 'indirect fire' weapons and are designed so that the projectile either follows a high arc trajectory before striking the target (Figure 7), or follows a flatter trajectory before exploding over the target.

In either case, the rationale behind developing such munitions is that the firer can engage the enemy without entering the enemy's line of sight—and ultimately the enemy's line of fire. However, the fact that indirect-fire weapons enable the firer to engage targets he or she cannot see has a number of potentially grave consequences in modern conflict. Primarily, this is because the firer is unable to determine what effect they have. Moreover, from a purely psychological perspective, the firer is disconnected from the target (Grossman, 1995, pp. 107–08). The 2003 siege of Monrovia, Liberia, demonstrated the effect of using mortars in built-up areas. Fighters from both sides of the conflict were unable, or unwilling, to hit purely military targets to the detriment of the local civilian population (Small Arms Survey, 2005, pp. 182–83).

Figure 10
Airburst munitions

The latest developments in airburst munitions (Figure 10) are worrying for exactly this reason. Unlike mortars, which are only sporadically used, some of these weapons are intended to replace standard assault rifles. This means that this ammunition could be among those most commonly used in any future infantry encounter. One fear is that combatants may use airburst munitions not only when they are certain of targets, but also when they are in doubt as to what is happening out of sight.

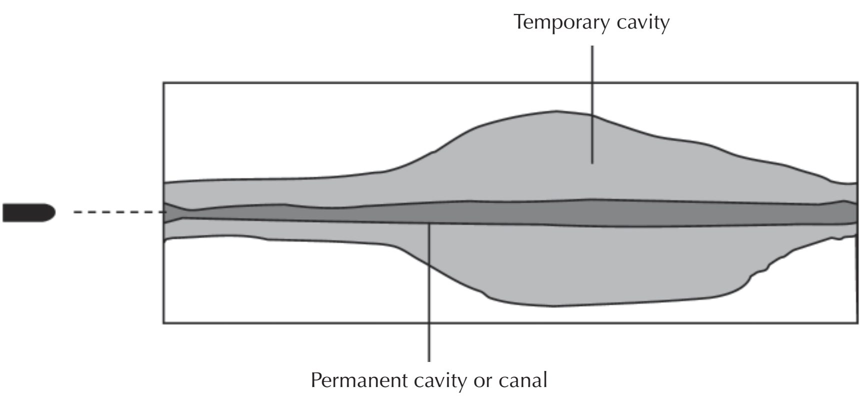
Wound ballistics

The different categories of ammunition (non-explosive or explosive) have important implications for the type and severity of wounds that they cause.[5]

Non-explosive projectiles

Wound ballistics is the study of the motion and effect of bullets and fragments on tissue (Di Maio, 1999, p. 53). The penetration of a bullet first creates a temporary cavity that corresponds to a very fast implosion of tissue. It leaves a permanent canal (see Figure 11). Most of the tissue is destroyed by the effect of the distension of the temporary cavity, rather than by the contact between the bullet and the tissue. It is worth noting, however, that the size of the temporary cavity does not determine the extent of the damage to the tissue because a large part of it is only distended rather than destroyed. The amount of kinetic energy

Figure 11
Permanent and temporary cavities



An anthropologist examines a skull shattered by a high-velocity bullet at the Guatemalan Forensic Anthropology Foundation (FAFG) in Guatemala City. FAFG devotes most of its time to exhuming bodies killed by the Guatemalan military during the country's 36-year civil war. © Victor James Blue/WPN

that is transferred to the body when hit determines the size of the permanent and temporary cavities (Di Maio, 1999, p. 55). Kinetic energy (KE) is a function of the mass and velocity of the projectile ($KE=1/2.m.v^2$).

Other factors affect the extent of the damage done by a bullet. Of these factors, the most notable is the characteristic (type, elasticity, density) of the organ hit. Organs that have a certain amount of elasticity, such as lungs or muscles, are better able to sustain a gunshot wound than solid organs such as the liver (Fackler, 1987; Di Maio, 1999, p. 55).

Fragmentation of the bullet can also increase the gravity of the wound. The breaking behaviour of a bullet depends on the distance it is fired from—there is more chance of fragmentation for a projectile shot from close range—and on other factors such as the type of metal of which it is made.

Another important factor in wound ballistics is the type of projectile used. Semi-jacketed bullets, such as soft-point and hollow-point bullets, have part of their core exposed at the top. These usually expand when they hit the target to assume a 'mushroom' shape (Di Maio, 1999, pp. 292–96).[6] Semi-jacketed bullets are usually used for hunting because they increase the chances of a kill, and in law enforcement because they tend to ricochet less, presenting less of a hazard to innocent bystanders in urban surroundings. Only fully jacketed bullets, however, are permitted for military use under international law (Small Arms Survey, 2005, pp. 22–23).

Explosive munitions

Explosive munitions launched by light weapons affect the human body in a different way to cartridge-based ammunition. Many light weapons use explosive munitions. They have three distinct effects: a ballistic effect, produced by fragments and sometimes referred to as the fragmentation effect; a blast effect; and a thermal effect.

It is important to note that a number of light weapons, such as portable anti-tank and anti-aircraft launchers, are intended to be used against materiel (vehicles, small buildings, and aircraft) rather than humans. In practice, however, humans can be—and often are—hit by such munitions, and are part of the collateral damage caused by the use of light weapons against materiel (Covey, 2004).

Explosive munitions produce metallic fragments that cause ballistic injuries. The resulting injuries depend on the characteristics of the fragment (velocity, mass, and shape) and those of the tissues hit (elasticity, density, and type). In contrast to bullets, fragments are often smaller and irregularly shaped, and can cause multiple wounds (VNH, 2004, p. 1.4). The impact of both thermal and blast effects depends on the distance between the body and the epicentre of the explosion (see Figure 12).

A thermal effect occurs when an individual is closest to the epicentre of the explosion, in which case he may be severely burned by the heat generated. These burns usually seriously complicate the treatment of other (ballistic) wounds (VNH, 2004, p. 1.4). The blast effect, which comes from the blast overpressure waves (also called sonic shock waves) created by the explosion, usually affects ears, lungs, and the digestive tract. These injuries increase in severity with the level of pressure and the length of exposure to them. Thermobaric weapons augment this blast effect by increasing the duration of the explosion, which is enhanced when it occurs in an enclosed space (such as a bunker). It should also be noted that the blast effect can cause further injuries by forcing individuals into nearby solid and sharp objects (VNH, 2004, p. 1.4).

Figure 12
Probability of injuries sustained from the detonation of explosive munitions

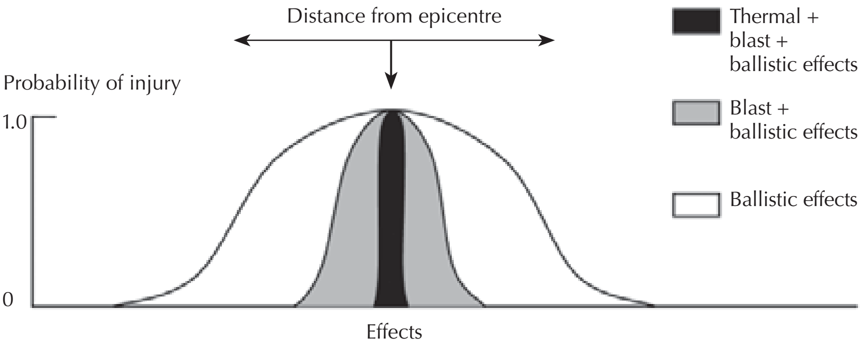


Figure adapted from Virtual Naval Hospital (2004), p. 1.3.

Recent developments in ammunition technology

There have been recent technological developments in ammunition in several fields. Of particular note are changes to the mass of rounds and to their destructive capacity.

Making ammunition lighter?

Caseless cartridges are 50 per cent lighter than traditional rounds of the same calibre. Their main advantage is to allow soldiers or law enforcement officers to carry larger amounts of ammunition, maintaining the same terminal ballistic effect. Caseless cartridges consist of a block of propellant with a bullet embedded inside. They have thus far been manufactured in 4.7 x 33 mm calibre and are currently used only in the Heckler & Koch G11 rifle, which is mainly used by the German Army special forces (Hogg and Weeks, 2000, p. 13; Hogg, 2002, p. 309).

Concerns about the weight of ammunition are not confined to small-calibre rounds. The United States is attempting to reduce the weight of mortar rounds and is testing composite materials (Cutshaw and Ness, 2004, p. 15). The trend towards ever lighter ammunition should, however, not be overstated. It is worth noting that recent combat experience in Iraq and Afghanistan has convinced many that the mass of the current 5.56 mm NATO round is insufficient on the battlefield, prompting the development of heavier and more powerful rounds. The American firm Remington has developed a 6.8 x 43 mm Special Purpose Cartridge, which fits the current M-16 and M-4 rifles if the weapons are equipped with a special calibre adapting device (Richardson, Richardson, and Biass, 2005, p. 12). Because of the cost of re-equipping an entire army, however, this change has so far been limited to Special Forces and some front-line combat units (Richardson, Richardson, and Biass, 2005, p. 12; Alpo, 2005, p. 64).

The destructive capacity of ammunition

Increased magazine capacity is a logical consequence of the process by which high-powered rifles have been progressively replaced by automatic rifles in military forces. Automatic rifles are designed to fire at a high cyclical rate, and to engage targets at relatively close ranges. Because of this, they fire smaller and lighter cartridges, which also enable a higher magazine capacity (Hogg and Weeks, 2000, p. 221). Magazine capacity for handguns is now frequently 13–14 rounds (Marchington, 1997, p. 8).

A single magazine can have up to 100 rounds for a light machine gun, and some weapons have double or triple side-by-side magazines, to enable them to be changed more quickly (DeClerq, 1999).

The destructive capability of light weapons ammunition has also increased. RPG rockets can now be equipped with 'tandem' warheads to produce double detonations (Small Arms Survey, 2004, p. 36). These warheads are designed to penetrate the explosive reactive armour (ERA) that normally provides additional protection to tanks against ATGWs.

Another important technological development, which has been employed in different types of projectiles, is the use of fuel-air explosives. In this case, the exploding device liberates particles of a volatile substance which reacts with the oxygen in the air to produce a second explosion of long duration (VNH, 2004, p. 1.4; Cutshaw and Ness, 2004, p. 15). Thermobaric weapons work in a similar fashion. They are mostly used in enclosed spaces, such as caves, where the overpressure waves they create prove particularly lethal. These weapons are being developed for infantry use in grenade form. A 40 mm grenade with a thermobaric warhead was tested in Afghanistan by US soldiers in 2003 (Burger Capozzi, 2003).

It should also be noted that ammunition has improved in terms of range and accuracy. To some extent these developments have been made necessary by the increasingly destructive power of ammunition because without the higher levels of accuracy these weapons could hurt friendly troops and cause undesirable collateral damage. The improvements may also be related to the growing cost of advanced ammunition, which makes every failed shot more expensive.

The Swiss company RUAG, for instance, is currently developing modular explosive penetrator (MEP) warheads that are adaptable to most RPG rockets and are used to defeat defensive features such as walls or piled sandbags. Their kinetic energy allows them to penetrate defences and explode in the space behind them, ensuring both 'wall-breaking' and limiting collateral damage (Jane's Information Group, 2005; Richardson, Richardson, and Biass, 2005, p. 18). Grenades are equipped with precision time-fuses and programming that allow them to explode exactly when needed (Cutshaw and Ness, 2004, p. 15).

Future developments in small arms and light weapons ammunition

A number of recent developments in small arms and light weapons ammunition suggest that its use and effects will change quite markedly in the coming decades. These new developments will also affect the way ammunition is categorized and studied.

Three new developments are of particular note. The first development is the introduction of airburst munitions that, as noted above, differ considerably from standard cartridge-based ammunition because they are fused to explode over targets. The most recent application of the technology is the OICW, which is still being tested in the United States (Small Arms Survey, 2006, p. 24). This weapon is small and light enough to fit into the small arms category, but has the explosive potential of some current light weapons. If it becomes widely available as a personal infantry weapon, it would blur the distinction between the existing categories.

A second development is the rapidly decreasing size of guided mortar bombs. At present, most guided mortar ammunition is larger in calibre than 120 mm.

For this reason it falls outside the United Nations definition of small arms and light weapons. Nonetheless, the fact that guided munitions have decreased in calibre over the past two decades—in some cases, such as the British Royal Ordnance Merlin, to 82 mm—suggests that this trend may well continue. If this occurs, another type of 'smart' (i.e. guided) munition will become commonplace in the small arms and light weapons category alongside such weapons as ATGWs and MANPADS.

The third development departs entirely from conventional principles of small arms and light weapons operation. Metal Storm is an Australian- and US-based initiative to replace the usual mechanical firing mechanism of small arms and light weapons with electronic impulses in order to achieve unprecedented rates of fire (Hiscock, 2003; Jane's Information Group, 2004). Inside the barrel, the conventional cartridge case is replaced by a series of bullets separated by a propellant load. While the technology is still at the developmental stage, its envisaged applications include a range of small arms and light weapons from handguns to grenade launchers. A 36-barrel gun of this type would be able to fire one million rounds per minute (Hiscock, 2003; BBC, 2004). The implications of this new technology are an increased lethality and, once again, a blurring of the division between small arms and light weapons.

Conclusions: the research and policy implications of ammunition characteristics

The physical attributes of ammunition have fundamental research and policy relevance. The United Nations definition of small arms and light weapons covers a range of weapons and ammunition that differs markedly in technology and in the effects they are capable of producing. These differences affect both the global distribution of weapons and the measures that can be taken to alleviate their unchecked proliferation.

While the technology involved in producing some small arms and light weapons ammunition is closely guarded, other types of ammunition have proliferated so widely and for so long that there are few technical barriers to their production and trade (see Chapter 2). This is the case, for instance, for cartridge-based ammunition and unguided missiles for light weapons. Countries that host production of guided systems, however, usually control the proliferation of knowledge as well as the proliferation of the weapons themselves. The small Stinger Missile Project Group (SPG), which attempted to limit the export of MANPADS to selected NATO countries, is a good example of this behaviour (Small Arms Survey, 2004, p. 92).

Some forms of ammunition for small arms and light weapons, including MANPADS and mortars over 75 mm, feature in international reporting mechanisms such as the United Nations Register of Conventional Arms. Others are not deemed a sufficient threat to international stability to warrant such scrutiny.

The revolution in military affairs has not significantly altered small arms and light weapons ammunition to date. The vast majority of ammunition currently used in conflicts around the world has changed little in several decades. Recent developments, particularly of light weapons, suggest, however, that the issues surrounding ammunition should not be expected to remain static in the future.

List of abbreviations

ACP	Auto Colt pistol
ATGW	Anti-tank guided weapon
BMG	Browning machine gun
GPMG	General purpose machine gun
ERA	Explosive reactive armour
HEAT	High explosive anti-tank
KE	Kinetic energy
LAW	Light anti-armour weapon
MANPADS	Man-portable air defence system
MEP	Modular explosive penetrator
NATO	North Atlantic Treaty Organisation
OCSW	Objective crew-served weapon
OICW	Objective individual combat weapon
RPG	Shoulder-fired anti-tank rocket launcher
SPG	Stinger Project Group

Endnotes

1 The shift from muzzle-loaded to breech-loaded weapons did not occur until the 1860s (Headrick, p. 85).
2 Another international definition of 'small arms and light weapons' can be found in UNGA, 2005, Section II, para. 4.
3 It should be noted, however, that there is disagreement about the definition of small-calibre ammunition; Ness and Williams define it as 'up to 14.5 mm calibre' (Ness and Williams, 2005, p. 3), and Courtney-Green as 'ammunition for weapons such as pistols, rifles and machine guns below 20 mm in calibre' (Courtney-Green, 1991, p. 24).
4 Research conducted at the 2004 *Eurosatory* Arms Exhibition, Villepinte, France, 14 June.
5 This section relies on Sellier and Kneubuehl (1994) for most of its information.
6 Semi-jacketed bullets may also not expand; it depends on their construction (the type of metal they are made of) and their velocity at the time of impact.

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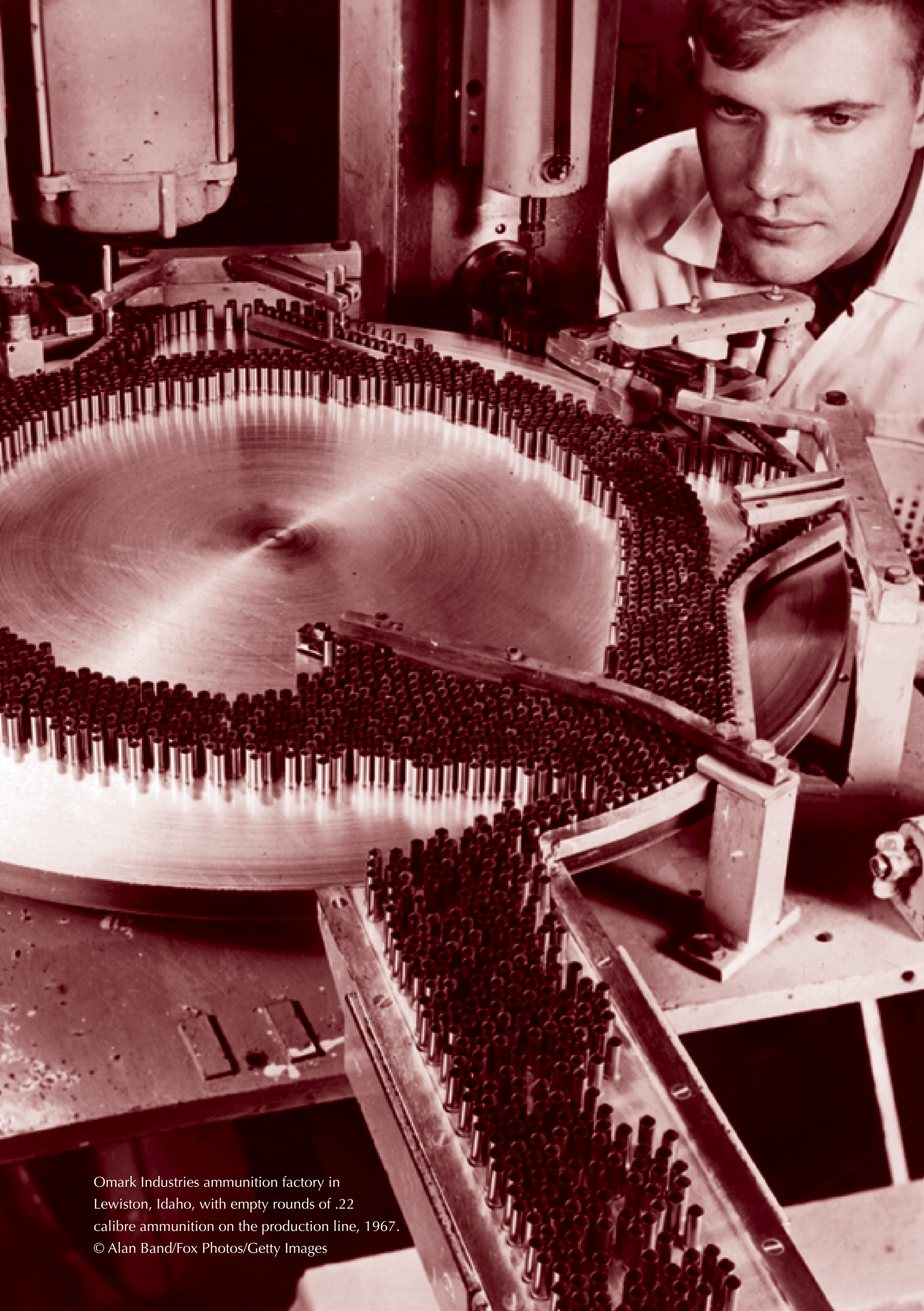

Omark Industries ammunition factory in Lewiston, Idaho, with empty rounds of .22 calibre ammunition on the production line, 1967.
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